THE PINYON-JUNIPER TYPE OF ARIZONA: EFFECTS OF GRAZING, FIRE, AND TREE CONTROL

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Contents

The Pinyon-Juniper Type of Arizona: Effects of Grazing, Fire, and Tree Control

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Introduction

Effects of invasions into former grasslands by pinyon, juniper, and associated woody species and of thickening of established stands have been observed by many range users, managers, and investigators. These invasions and the growth of trees and unpalatable shrubs have reduced the quantity and quality of forage available for livestock, and increased the difficulty and cost of handling animals. Also, suppression of palatable understory browse species by overstory evergreens has reduced the forage supply for both game and livestock.

Pinyon-juniper woodlands yield some wood products, and at present their most valuable tree product is pinyon Christmas trees. Probably most of the salable Christmas trees grow on old burns and tree-control areas. Suitable trees are rarely found in dense stands or in the lower fringes of the type. Both pinyon and juniper have been an important source of fuelwood and fenceposts (Howell 1941, Reveal 1944).[2] However, the demand for fuelwood has steadily declined as that product has been replaced by coal, oil, and natural gas. While juniper of suitable quality makes excellent fenceposts and is widely used for that purpose, the increased use of metal posts and the lack of stands of suitable-quality trees has further reduced the importance of this product.

Charcoal can be produced from pinyon and juniper trees, but it has not been developed commercially. Resins from pinyon are excellent, but they are not being harvested in sufficient quantities or at low enough cost to compete with resins from other pines or with synthetics (Deaver and Haskell 1955). Although veneer has been produced on a test basis from large bolts of alligator juniper, large trees are too few and scattered to support a commercial operation. The possibilities of producing wood molasses, paper, or particle board have not attracted industry because of the high harvesting costs in pinyon-juniper stands.

Pinyon nuts offer an important source of income for the Indians of the Southwest when there are good crops. Great variations in the nut crop from year to year, however, make this an unreliable source of income from any specific area.

High costs of harvesting and the slow growth rate of pinyon and juniper (Howell 1941, Reveal 1944, Herman 1953, Myers 1962) have discouraged the management of these dwarf forests for the production of wood products. Because there is high demand for the forage products and low demand for the tree products obtained from the pinyon-juniper type, trees are being removed or reduced on large areas in an attempt to increase forage production for livestock and, in some places, for big game. How to increase the economic value of pinyon-juniper woodlands in Arizona hinges on the answer to the question "Can and should a tree type be economically converted and successfully managed as a grassland type?"

This report presents available information on forage values and use of pinyon-juniper woodlands in Arizona. Information includes: (1) Characteristics of the pinyon-juniper type, (2) tree invasions and increases, (3) effects of tree increases on other plants, (4) principal methods used to control juniper and pinyon, (5) response of vegetation to tree control, and (6) costs and resulting benefits of control.

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[2] Names and dates in parentheses refer to Literature Cited, p. 28.

The Pinyon-Juniper Type: Extent, Location, and Stand Characteristics

Pinyon-juniper woodlands cover about 14 million acres in Arizona, more than four times the area of commercial forests in the State. The pinyon-juniper type occupies 60 million acres in the western United States, mostly in Nevada, Utah, Colorado, Arizona, New Mexico, and western Texas. (U.S.D.A. Forest Service 1958.)

Of the three most common species of juniper in Arizona–Utah,[3] one-seed, and alligator—Utah juniper is the most widely distributed and most abundant. This species may be either single- or multiple-stemmed but is more often single-stemmed, and the foilage does not tend to be bunched at the tips of the branches, as is characteristic of one-seed juniper. Fruits of Utah juniper are mealy when mature, and they are 7 to 18 millimeters in diameter. Nearly all trees bear both pollen and seeds.

One-seed juniper trees usually have multiple stems. The bark is stringy, and the foliage tends to be bunched at the ends of the branches. Fruits at maturity are succulent and about half as large as the fruits of Utah juniper. Trees are male or female.

Alligator juniper is the largest of the junipers in Arizona, and may be 65 feet at maturity. It seldoms grows in pure stands but usually is mixed with other junipers, and is often in the understory of ponderosa pine forests. The common name, alligator, is derived from the bark's rectangular plates. Alligator juniper is the only juniper in Arizona that sprouts when cut at ground level. Sprouting ability is almost universal in young trees. Old trees with trunks 2 feet or more in diameter can be cut or girdled with little risk of sprouting.

Pinyon is a small, two-needle (sometimes one- or three-needle) pine tree that attains a height up to 35 feet and a trunk diameter up to 30 inches. Crowns of young trees are broadly conical, and those of old trees are spreading or flat-topped. Pinyon is more abundant in the woodland type at its upper elevational limits. Pinyon nuts are borne in small cones and are dispersed in September and October.

Minor tree species within the woodland type include ponderosa pine and Emory oak.

The pinyon-juniper type is primarily in the northern half of the State at intermediate elevations (4,500 to 7,000 feet) (fig. 1). In southern Arizona, juniper merges with the oak woodland.

In the northern one-fourth of the State Utah juniper and pinyon are dominant. In this area the most common understory plant is big sagebrush, and the climate is marked by cold, moist winters.

South of the Mogollon Rim the dominant species at the higher elevations is alligator juniper. Utah juniper and pinyon dominate the middle elevations, and Utah juniper dominates the lower elevations. In this subtype pinyon-juniper is replaced in part by chaparral, with which it often merges. The climate is typical of the warm, moist winters of the Arizona chaparral. The understory includes a wide variety of grasses and forbs.

North of the Mogollon Rim old mixed stands primarily of pinyon and one-seed juniper with minor amounts of Utah and alligator juniper are at the higher elevations. Scattered stands of one-seed juniper are at the lower elevations. The usual understory is blue grama, snakeweed, and rabbitbrush. Winters in this subtype are drier than in the State's other two subtypes.

Over a large part of the type, juniper grows in open, scattered stands. Young stands can be found throughout the type where young trees are invading grassland openings and old burns and where they are becoming reestablished on areas cleared of juniper (fig. 2). Dense stands of even-aged trees can dominate a site so that the soil surface is largely barren of understory grasses and forbs (fig. 3).

The principal species of pinyon-juniper woodlands are listed below by plant-form classes as defined by Arnold (1955).

COMMON PLANTS OF THE PINYON-JUNIPER TYPE

Trees:
- Juniper, alligator
- Juniper, one-seed
- Juniper, Utah
- Oak, Emory
- Pine, ponderosa
- Pinyon

Shrubs:
- Algerita
- Blackbrush
- Cliffrose
- Dalea
- Ephedra
- Eriogonum, Simpson
- Eriogonum, Wright
- Horsebrush, Gray
- Penstemon, toadflax
- Oak, shrub live
- Rabbitbrush, rubber
- Sagebrush, big
- Sagebrush, fringed

Shrubs:—Con.
- Saltbush, fourwing
- Sumac, skunkbush
- Winterfat, common

Other woody perennials:
- Agave
- Cactus, pincushion or mammillaria
- Cholla
- Pricklypear
- Sacahuista
- Yucca

Mid-grasses:
- Bluegrass, mutton
- Dropseed, sand
- Galleta
- Grama, black
- Grama, side-oats
- Muhly, spike

[3] Common and botanical names for species are given on p. 27.

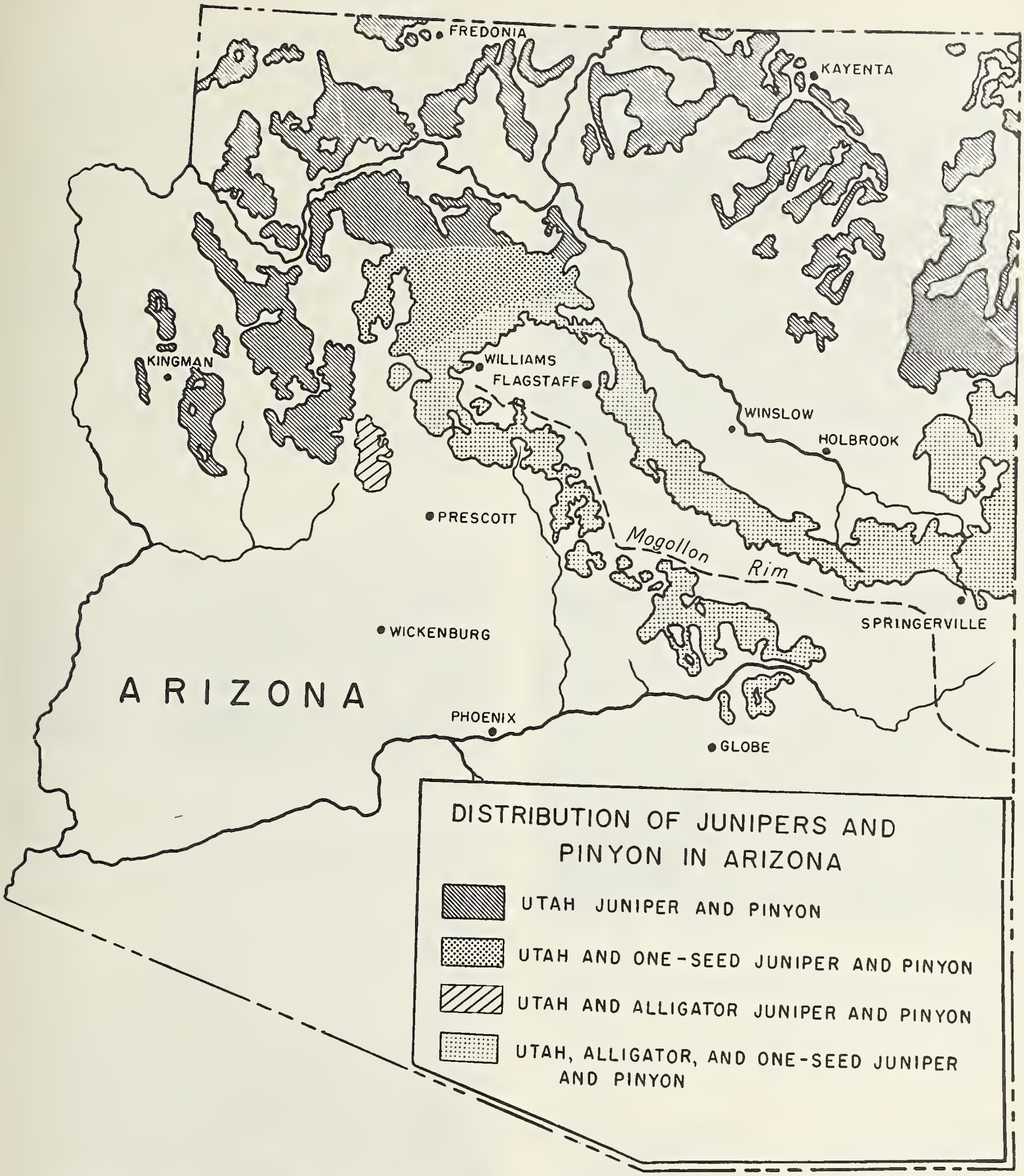

FIGURE 1.—Location of pinyon-juniper type in Arizona. Adapted from Nichol (1952) and Whiting (1942).

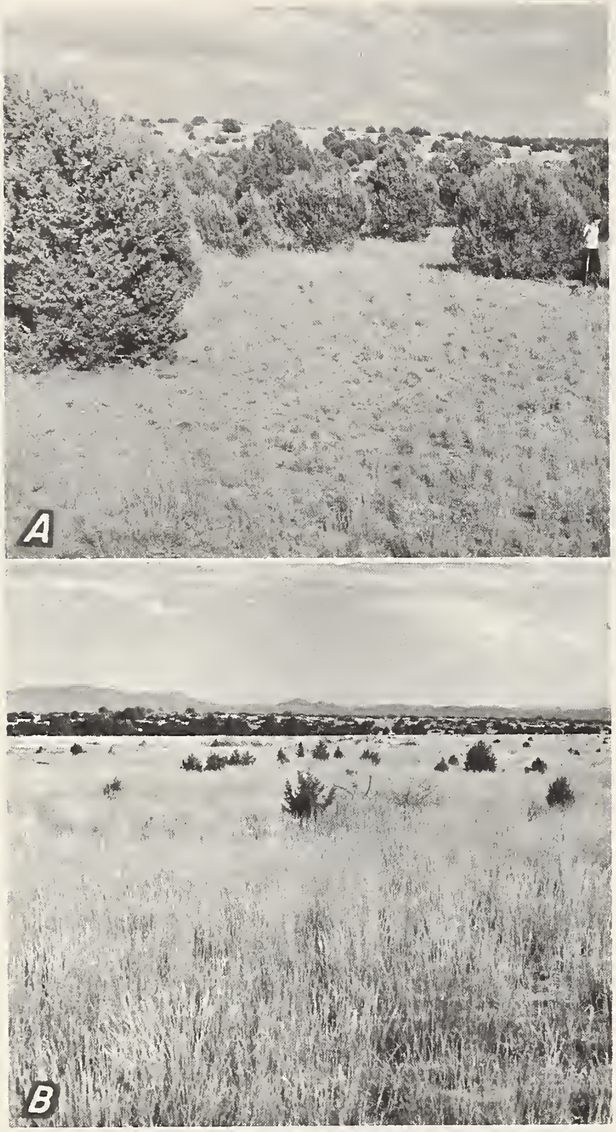

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FIGURE 2.—*A*, Scattered stand of Utah juniper in what once was a grassland type; *B*, young stand of trees is becoming reestablished on an area from which juniper had previously been removed.

COMMON PLANTS OF THE PINYON-JUNIPER TYPE—continued

Mid-grasses—Con.
- Needle-and-thread
- Ricegrass, Indian
- Squirreltail, bottle-brush
- Three-awn
- Tridens, slim
- Wheatgrass, western
- Vine-mesquite

Short-grasses:
- Curlymesquite

Short-grasses—Con.
- Grama, blue
- Junegrass, prairie
- Muhly, red
- Three-awn, red
- Tridens, hairy
- Tumblegrass
- Wolftail

Mid- and short-forbs:
- Aster
- Bladderpod

COMMON PLANTS OF THE PINYON-JUNIPER TYPE—continued

Mid-and Short-forbs—Con.
- Bundleflower, James
- Deervetch
- Eriogonum (herbaceous)
- Evolvulus, Arizona
- Globemallow
- Flax, Lewis
- Fleabane
- Groundsel
- Hoarhound, common
- Hymenopappus
- Milkvetch
- Nightshade
- Penstemon
- Sagebrush (herbaceous)
- Scurfpea, slimflower
- Verbena

Prostrate grasses and forbs:
- Fluffgrass
- Loco, prostrate

Prostrate grasses and forbs—Con.
- Muhly, ring
- Phlox, desert
- Pussytoes
- Three-awn, Fendler
- Yarrow, western

Half-shrubs:
- Actinea, Cooper
- Groundsel, broom
- Menodora, rough
- Snakeweed, broom

Annuals:
- Amaranth
- Euphorbia
- Goldeneye, annual
- Goldenweed
- Grama, needle
- Grama, sixweeks
- Knotweed
- Russianthistle
- Three-awn, sixweeks

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FIGURE 3.—*A*, Dense young stand of Utah juniper that became established about 1900. Trees so dominate the site that understory grasses occur only in isolated patches. *B*, Old mixed stand of pinyon and one-seed juniper.

Methods of Study

Ecological studies were made during 1952–60 to determine the possibilities of improving forage production on the pinyon-juniper type. These studies included: (1) Remeasurement in 1953 of grazed and protected plots established in 1939 and 1940 at 14 locations in northern and central Arizona (fig. 4); [4] (2) detailed studies of the relationship between tree canopy and understory vegetation; and (3) observations and measurements of vegetation changes on 16 burns. Changes for 10 of the burns are described in this report. The line intercept method of Canfield (1941) was the principal technique used.

Methods of controlling the pinyon and juniper as a range management measure were observed, and costs of various kinds of control measures on more than one-half million acres were compiled. Project and experimental burns were evaluated on the Coconino National Forest and Hualpai Indian Reservation.

To evaluate the benefits obtained from control, these studies were supplemented by measurements of subsequent forage production changes, primarily on the Apache Indian Reservation. Twenty-nine control projects were studied; transects were measured in a controlled area and on an adjacent untreated area.

Because juniper and pinyon control often leaves considerable slash on the ground, the effects of this slash and its removal were evaluated by transects, herbage production determinations, and measurements of the effects of slash burning on soil characteristics.

FIGURE 4.—Location of pinyon-juniper study areas in northern and central Arizona.

Successional Changes in the Pinyon-Juniper Type

Factors that influence succession are considered under (1) ecological superiority with regard to lifespan and height of the invading trees, (2) propagation habits, (3) climatic conditions that favor seed germination and seedling survival, (4) grazing, and (5) fire.

Superiority of Trees

In height and longevity pinyons and junipers have decided advantages over understory grasses and forbs. Clements (1905) recognized that grassland communities are changed more by the invasion of larger plants than by plants smaller or the same size as those of the established vegetation. Pinyons and junipers as invaders of grassland communities were also recognized by Leopold (1924). He considered grassland openings in the pinyon-juniper type to be temporary communities resulting from fire. Reinvasion of these openings by trees may be regarded as succession toward rather than away from the climax.

Pinyon-juniper invasions of protected grassland communities and the more rapid growth of the established trees indicates their ability to dominate understory plants. Such invasions of grasslands, therefore, seem a natural process of plant succession.

Propagation and Factors That Affect Reproduction

Reproduction of pinyon and Utah and one-seed junipers depends entirely upon the production of seeds. Alligator juniper is the only sprouting species in Arizona. The junipers produce many seeds in most years, but abundant seed is produced by pinyon in relatively few years. Seeds of the junipers fall throughout the year, but most

[4] Study areas shown in fig. 4 are exclusive of burns studied in developing fig. 12, p. 13, but for which no data is otherwise presented.

drop in autumn. Pinyon nuts fall in September and October.

Dissemination of seed by animals has been important in the invasion of grasslands by juniper and pinyon (Parker 1945). Examination of droppings indicates that small mammals, birds, and coyotes eat fruits of junipers and dispense the seeds. Dispersal by birds is indicated by the location of young trees along fences. Livestock, particularly sheep, also disperse juniper seeds. Seeds passed by animals germinate faster than other seeds (Johnsen 1962). Flowing water also transports seed.

Juniper seeds may remain viable for many years. Johnsen (1959) found that 16 percent of the alligator juniper seeds he studied were viable after 9 years. He also found that 54 percent of one-seed juniper seeds germinated after 21 years, and that 17 percent of Utah juniper germinated after 45 years. Johnsen concluded that a few years of drought following a good seed crop would not seriously affect the seed viability.

Climate and Seedling Establishment

Invasions probably are favored by a combination of good seed years followed by years of favorable moisture. For example, many juniper stands apparently were established in 1905 and 1919; in both years precipitation was more than 1½ times the longtime average. In years of above-normal moisture, seedling trees may take advantage of extra moisture and become successfully established in even the best stands of grass.

Responses on Grazed and Ungrazed Plots

Response of the principal species to protection and grazing is indicated by the gains and losses in canopy and basal intercepts. These comparisons only indicate trends that result from grazing because the plots were located on the open range, and the intensity of grazing during the 1940–53 period is not known. Also, site strongly influences the understory vegetation in the pinyon-juniper type. However, changes in the tree overstory and understory vegetation were quite consistent on the 14 plots studied, so only average changes are presented in table 1.

Each value is an average of 270 50-foot line transects located in plots at 14 study areas widely scattered over northern and central Arizona. At each study area, plots 100 feet square were established both within exclosures fenced against grazing and on an adjacent grazed range. Each plot was divided into two 100- by 50-foot subplots, and ten 50-foot transects were randomly located within each subplot except at one area, where only five transects were located in each subplot. Transects were first measured in 1940, by the procedures described by Canfield (1941), and then were remeasured in 1953. Canopy intercepts were recorded for trees, shrubs, other woody perennials, and half-shrubs. Basal intercepts were recorded for perennial and annual grasses and forbs.

TABLE 1.—*Intercept between 1940 and 1953 of principal species of the pinyon-juniper type on protected and grazed plots* [1]

Principal species by plant-form class [2]	Protected			Grazed		
	1940	1953	Gain or loss	1940	1953	Gain or loss
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Trees:						
Juniper	2. 232	5. 896	+3. 664	1. 353	3. 248	+1. 895
Pinyon	. 311	. 488	+. 177	1. 062	1. 965	+. 903
Ponderosa pine	(3)	. 030	+. 030	(3)	(3)	(3)
Total	2. 543	6. 414	+3. 871	2. 415	5. 213	+2. 798
Shrubs:						
Shrubby eriogonums	. 462	1. 258	+. 796	. 272	. 437	+. 165
Rabbitbrush	. 733	. 577	—. 156	1. 188	. 796	—. 392
Shrub live oak	. 551	. 377	—. 174	. 184	. 548	+. 364
Algerita	. 336	. 403	+. 067	. 381	. 368	—. 013
Cliffrose	. 102	. 317	+. 215	. 023	. 017	—. 006
Fourwing saltbush	. 060	. 201	+. 141	(3)	(3)	(3)
Fringed sagebrush	. 041	. 185	+. 144	. 005	. 026	+. 021
Shrubby penstemon	. 140	. 125	—. 015	. 071	. 136	+. 065
Skunkbush	. 094	. 096	+. 002	. 080	. 224	+. 144
Horsebrush	. 034	. 104	+. 070	. 006	. 006	. 000
Ephedra	(3)	. 098	+. 098	(3)	(3)	(3)
Others	. 047	. 090	+. 043	. 299	. 264	—. 035
Total	2. 600	3. 831	+1. 231	2. 509	2. 822	+. 313
Other woody plants:						
Pricklypear and cholla	. 096	. 094	—. 002	. 194	. 152	—. 042
Pincushion cactus	(3)	. 004	+. 004	(3)	(3)	(3)
Yucca	. 002	. 024	+. 022	(3)	(3)	(3)
Total	. 098	. 122	+. 024	. 194	. 152	—. 042

TABLE 1.—*Intercept between 1940 and 1953 of principal species of the pinyon-juniper type on protected and grazed plots*[1]—Continued

Principal species by plant-form class[2]	Protected			Grazed		
	1940	1953	Gain or loss	1940	1953	Gain or loss
Mid-grasses:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Squirreltail	.136	.233	+.097	.113	.124	+.011
Side-oats grama	.193	.222	+.029	.220	.083	−.137
Western wheatgrass	.066	.178	+.112	.056	.103	+.047
Mutton bluegrass	(3)	.110	+.110	.002	.018	+.016
Black grama	.038	.053	+.015	.005	.003	−.002
Spike muhly	.005	.050	+.045	.005	.013	+.008
Galleta	.064	.036	−.028	.020	.011	−.009
Sand dropseed	.084	.032	−.052	.054	.040	−.014
Three-awn	.082	.025	−.057	.090	.017	−.073
Needle-and-thread	.009	.012	+.003	.001	(3)	−.001
Others	.005	.008	+.003	.002	.024	+.022
Total	.682	.959	+.277	.568	.436	−.132
Short-grasses:						
Blue grama	4.583	2.835	−1.748	4.338	3.517	−.821
Red three-awn	.433	.251	−.182	.321	.199	−.122
Junegrass	.011	.042	+.031	.006	.025	+.019
Wolftail	.008	.017	+.009	.002	.017	+.015
Red muhly	.095	.015	−.080	.001	.017	+.016
Hairy tridens	.027	.003	−.024	.047	.030	−.017
Others	.004	.006	+.002	(3)	.001	+.001
Total	5.161	3.169	−1.992	4.715	3.806	−.909
Mid- and short-forbs:						
Eriogonums	.018	.047	+.029	.005	.008	+.003
Aster	.060	.036	−.024	.047	.062	+.015
Globemallow	.029	.026	−.003	.010	.028	+.018
Milkvetch	.011	.012	+.001	.011	.010	−.001
Evolvulus	(3)	.011	+.011	(3)	.005	+.005
Penstemon	.014	.001	−.013	.004	.017	+.013
Others	.075	.100	+.025	.015	.058	+.043
Total	.207	.233	+.026	.092	.188	+.096
Prostrate species:						
Ring muhly	.393	.054	−.339	.665	.356	−.309
Prostrate loco	.000	.006	+.006	.000	.018	+.018
Pussytoes	.000	.003	+.003	.000	.000	.000
Western yarrow	.000	.002	+.002	.000	.002	+.002
Fendler three-awn	.004	.001	−.003	.000	.000	.000
Total	.397	.066	−.331	.665	.376	−.289
Half-shrubs:						
Snakeweed	3.797	1.429	−2.368	4.777	1.844	−2.933
Actinea	.673	.049	−.624	.706	.032	−.674
Menodora	.002	.029	+.027	.008	.001	−.007
Others	.277	.017	−.260	.051	.060	+.009
Total	4.749	1.524	−3.225	5.542	1.937	−3.605
Annual grasses and forbs:						
Annual spurges	(4)	.056		(4)	.030	
Annual aplopappus	(4)	.010		(4)	.032	
Others	(4)	.005		(4)	.085	
Total		.071			.147	

[1] Each value is an average of 250 50-foot line transects that were permanently located at random in 14 study plots in 1940 and remeasured in 1953.

[2] Trees, shrubs, other woody plants, and half-shrubs were measured by canopy intercept, and plants in the other groups by basal intercept.

[3] No plants found.

[4] No measurements were recorded in 1940.

Trees

All tree species increased during the 1940–53 period. Intercepts by trees as a class increased about 150 percent on the 14 study areas, under both protection and grazing (fig. 5). The increases were due largely to growth of established trees, although some new trees became established.

Shrubs

Shrubs as a class had a greater increase in canopy intercept on the protected plots than on the grazed plots. On the protected plots, all but 3 of 12 shrubs gained in canopy intercept. On the grazed plots, five species increased and four decreased. Cliffrose and Wright and Simpson eriogonums, which are palatable to cattle and sheep, benefited markedly by protection. Algerita increased slightly where protected and decreased slightly under grazing, while fourwing saltbush, not found on the grazed plots, increased markedly on ungrazed plots. Shrub live oak and fringed sagebrush may have benefited by grazing. Rabbitbrush, an unpalatable species, decreased on both protected and grazed plots; it decreased more on the grazed plots, but it still occupied a greater area on the grazed than on the protected plots. Thus, except for rabbitbrush, there was a general relationship between palatability to livestock and changes in intercept as influenced by grazing.

Other Woody Plants

Other woody perennials are generally of little importance in the woodland type, but they sometimes become abundant locally. As a class, they maintained their position in protected plant communities, and were not crowded out by other species. The intercept of pricklypears remained unchanged for the protected plots but decreased slightly on the grazed plots. No pincushion cacti or mammillaria were on protected or grazed plots in 1940, and a small amount was recorded in 1953 on the protected plots. A small increase of canopy intercept of yuccas occurred on the protected plots.

At several sites cacti were more abundant within the exclosures than on the open range. Several small plants that had been trampled by livestock were found at these sites.

Mid-Grasses

Mid-grasses are an important part of the herbaceous understory, because they produce the most palatable herbage for the space occupied. However, they were not as abundant as short-grasses. The increases in mid-grasses were associated with decreases in the short-grasses and half-shrubs. Side-oats grama, squirreltail, western wheatgrass, and mutton bluegrass were the most abundant mid-grasses on the sites studied.

Under protection, all but three of the mid-grasses increased in basal intercept, despite the increased growth of overstory juniper and pinyon. Squirreltail, western wheatgrass, and mutton bluegrass—all cool-season grasses—increased the most. Galleta, sand dropseed, and the three-awns were the three grasses that decreased under pro-

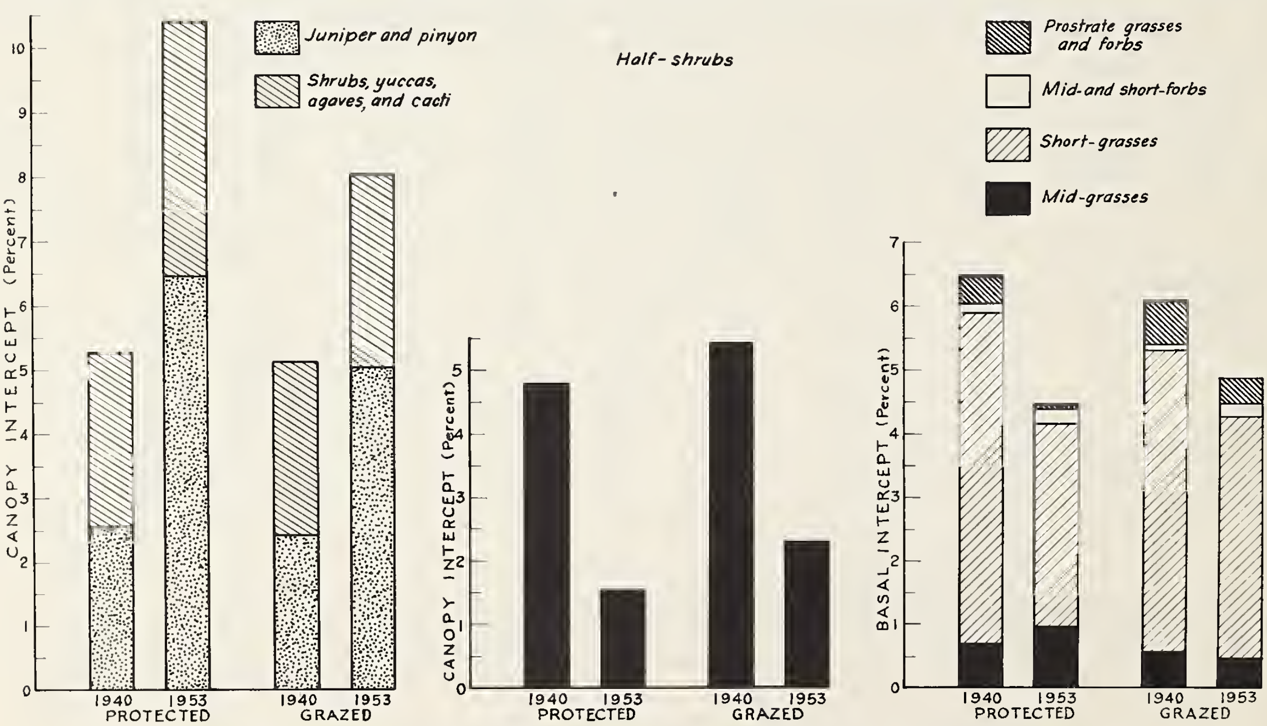

FIGURE 5.—Response of plants to protection and grazing, grouped by plant-form classes.

tection; the latter two tend to be short lived. Galleta decreased about the same percentage on both the grazed and ungrazed plots.

On the grazed plots, the mid-grasses as a class decreased. Only squirreltail, western wheatgrass, mutton bluegrass, and spike muhly increased. All the increases were less than those on the protected plots. Six species decreased. Side-oats grama decreased the most, more than 60 percent. Except for sand dropseed and those species grouped as others, all species of mid-grasses had lower basal intercepts on the grazed plots than on the protected plots.

Short-Grasses

The short-grasses as a group declined and were replaced by mid-grasses, shrubs, and trees. Blue grama covered more area than any other herbaceous species on the plots studied.

Blue grama, red three-awn, red muhly, and hairy tridens showed marked losses where protected from grazing from 1940 to 1953. Junegrass and wolftail increased slightly under protection.

Blue grama, red three-awn, and hairy tridens decreased on the grazed plots, although not as much as on the protected plots. Red muhly increased under grazing and decreased under protection. The cover of short-grasses on grazed plots was greater than on protected plots in 1953, even though this relationship was reversed in 1940 when the plots were established. In general, the short-grasses withstood grazing better than the taller mid-grasses.

Mid- and Short-Forbs

The mid- and short-forb group is a mixed class of broad-leaved herbaceous plants. The group was comparatively unimportant because it comprised only a minor part of the understory vegetation. However, it was abundant locally. The eriogonums, milkvetches, and evolvulus increased and occupied a somewhat larger area on the protected plots than on the grazed plots. On the other hand, asters, globemallows, and species of penstemon decreased under protection and increased under grazing. The group as a whole increased under grazing about three times as much as under protection. In 1953, the population was still slightly greater on the protected plots than on the grazed plots.

Prostrate Species

Plants whose main vegetative height growth usually averaged less than 2 inches (although that for flowerstalks was somewhat more) were called prostrate species. Ring muhly was the most common species found on the plots. It decreased about the same under both protection and grazing from 1940 to 1953, but it still occupied seven times more area on grazed than on protected plots. Fendler three-awn and fluffgrass, though nonexistent or sparse on the plots, became abundant on local overgrazed ranges.

Half-Shrubs

Half-shrubs are low, short-lived plants with woody bases. Broom snakeweed was by far the most abundant species. Snakeweed decreased markedly between 1940 and 1953 on both protected and grazed plots. Cooper actinea, broom groundsel, and other minor species showed similar responses to protection and grazing. Although rough menodora increased on the protected plots and decreased on the grazed plots, the changes were insignificant because of the small amounts present.

Half-shrubs are generally most abundant on heavily grazed ranges where they reproduce most successfully. Half-shrubs may become established even in good stands of perennial grass in years of above-normal precipitation.

Annual Grasses and Forbs

Annual grasses and forbs reproduce solely by seed, and they complete their life cycles in one growing season. They are most common where some disturbing influence reduces perennial plants.

No measurements were recorded for annuals in 1940. In 1953, there were twice as many annuals on the grazed plots as on the protected plots. Grazing probably favors annuals, but even on the grazed ranges, the annuals were only a very minor part of the total plant cover.

Successional Displacement

Changes in trees and half-shrubs under both protection and grazing were in proportion to the amount present on these plots in 1940. Shrubs, other woody perennials, and the mid-grasses increased under protection. The short-grasses and prostrate grasses and forbs decreased under protection.

Shrubs and mid-grasses occupied more space on the protected plots in 1953 than on the grazed plots. In contrast, short-grasses, prostrate species, and annuals occupied more space on the grazed plots than on the protected plots in 1953, even though they decreased under both protection and grazing. These comparisons suggest that grazing may favor short-grasses, prostrate species, and annuals over palatable shrubs and mid-grasses. This is interesting because a woodland range with a good mixture of mid-grasses and short-grasses usually is considered to be in better range condition than a range mostly of short-grasses, prostrate species, and annuals.

However, the amount of understory vegetation may be controlled by the tree overstory and may not reflect grazing effects. Displacement of understory plants by juniper resulted in a loss of 70 percent of the perennial grasses, forbs, and half-shrubs between 1940 and 1953 at one of the protected plots (fig. 6).

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FIGURE 6.—*A*, A 1940 photo of the 13-mile range study plot on the Kaibab National Forest; *B*, repeat photo taken in 1953. Note growth of juniper and loss of grass even though the plot had been protected from grazing.

Response to Fire

Fire has been considered a natural ecological factor that repels invasions of juniper and pinyon and reduces old established stands to grassland communities[5] (Leopold 1924, Parker 1945, Humphrey 1950). Leopold points to the widespread distribution of charred stumps as evidence of recurring fires throughout the juniper type. He considered the recurrence of fires to be the main factor in maintaining grassland openings.

Sixteen accidental or natural burns in the pinyon-juniper type were studied to determine dates of burning and subsequent ecological changes. Approximate dates of burning were determined by annual ring counts on sections cut from old fire-scarred pinyons. Pinyons were used for ring counts in preference to junipers because their rings more reliably indicate years. Where fire-scarred trees were unavailable, ring counts were made on pinyons that had become established within the burned-over area. While the latter procedure gave no exact date of burning, it did indicate that the fire occurred prior to a certain year.

Aerial views show that burns often were clean on flat to gently rolling terrain (fig. 7*A*). In rough terrain, islands of unburned trees were left on hills and ridges. Tree stands growing on dry hills and ridges may have been too open to carry fire (fig. 7*B*).

To evaluate early stages of successional recovery after a fire, transects (Canfield 1941) were lo-

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FIGURE 7.—*A*, Aerial view of a burn shows unburned islands; *B*, junipers on the ridge possibly were too scattered to carry fire. The valley is now being reinvaded by small trees.

[5] Huss, Donald L. Factors influencing plant succession following fire in Ashe-juniper woodland types in Real County, Tex. (Unpublished master's thesis on file at Tex. Agr. and Mech. Col., College Station.)

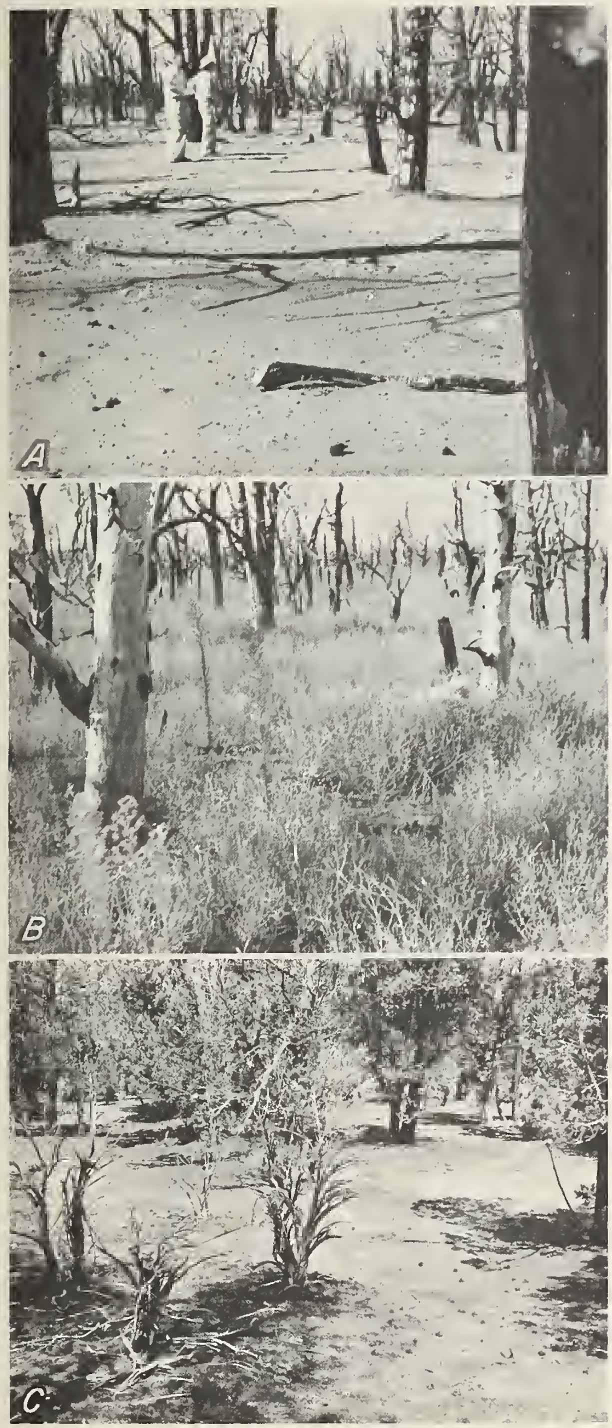

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FIGURE 8.—*A*, Burned-over stand of pinyon-juniper on the Hualpai Indian Reservation soon after the fire in 1953; *B*, natural vegetation at same point one growing season after the fire; *C*, adjacent unburned stand has sparse understory vegetation. (Photos *A* and *B* courtesy of Bureau of Indian Affairs.)

cated in adjacent unburned and burned sites at two areas of the 1953 Hualpai Indian Reservation burn. Measurements were made in 1954 before the start of the summer growing season and in 1955, 1956, and 1958.

Transect data showed that before the fire the forest was a dense stand of trees. Pinyon made up 54 percent of the stand. In 1954, the burn was still a charred forest. Soil surfaces were burned clean of both vegetation and litter (fig. 8). No understory vegetation remained.

In contrast, the adjacent unburned areas had a tree and shrub cover of 37 to 46 percent and a litter intercept of 50 to 60 percent. Understory vegetation was sparse. Trees averaged 360 per acre; 40 percent were pinyon.

Annual plants, the first invaders, became abundant during the second growing season after the burn. By the end of the third growing season (1955), annuals were very abundant; Russianthistle was a prominent species. Annuals decreased in 1956 and 1958, and were replaced by perennial forbs and half-shrubs such as globemallow and toadflax penstemon.

The perennial grasses were slower in becoming reestablished, but had made considerable recovery by 1958. A large part of the increase in grasses on the burned transects was by seeded species, however, which came in from nearby areas that had been seeded.

An old burn west of Grand Canyon Village on the road to Supai illustrates a conversion of a pinyon-juniper stand to a big sagebrush community (fig. 9). Annual ring counts on a pinyon growing through a charred snag indicated that the area had burned prior to 1875. Aerial views of the burn showed that fire swept from the south. Numerous islands of unburned trees indicated that the original stand density, composition, or other factors were not uniform. The unburned islands of live trees were on hills and ridges.

F-503467

FIGURE 9.—A sagebrush community that developed on the burned-over area near Supai, Ariz.

Transect measurements of the Supai burn were compared with measurements of adjacent unburned pinyon-juniper stands (table 2). The intercept of young pinyon and juniper on the burned area was less than a hundredth of the overstory intercept of trees in the unburned stands. In contrast, the intercept of sagebrush, the prevailing shrub, was more than seven times greater on the burned than on the unburned area. The combined basal intercept of perennial grasses and forbs within the sagebrush-fire community was 82 percent of that recorded for the unburned pinyon-juniper stands. Sagebrush nearly excluded juniper and pinyon and restricted the grasses. Snakeweed was much more abundant on the burned area.

A burned area 12 miles east of Flagstaff, Ariz., near Cosnino, was the site of two fires (figs. 10 and 11). An examination of tree rings in old fire-scarred pinyons along the edge of the burn indicated the first fire occurred around 1885 and the second fire in the early 1920's. The second fire apparently reburned the northeastern two-thirds of the old burn.

Two communities have developed on the Cosnino burn. The once-burned southwest third was characterized by a rabbitbrush-blue grama community (fig. 11*A*). The northeast portion, which burned twice, was dominated by blue grama (fig. 11*B*). Pinyon and juniper trees in the southwest end of the burn were considerably larger than those in the reburned area.

Transect measurements of burned and unburned communities at Cosnino may be compared in table 2. While the unburned pinyon-juniper represents a heavy stand, the canopy intercept covered only 43 percent of the ground surface (fig. 10). Understory plants were very sparse.

Rabbitbrush in the southwest end of the Cosnino burn covered 12 percent of the ground surface. On the adjacent unburned area, rabbitbrush was so sparse that none occurred in the transects. The pinyon-juniper intercept in the rabbitbrush community was only 12 percent of that in the unburned stand. The basal intercept of perennial grasses and forbs in the rabbitbrush community was 14 times that in the unburned pinyon and juniper stands. Half-shrubs occupied about the same area in both communities, while annuals were somewhat greater in the rabbitbrush community.

Blue grama dominated the grassland community at the northeast end of the Cosnino burn. The combined basal intercept of perennial grasses and forbs in the blue grama community was 35 times that of adjacent unburned pinyon-juniper stands. Young trees and rabbitbrush together occupied less than 1 percent of the area. Half-shrubs and annuals were sparser in the blue grama community than in the adjacent unburned tree stands.

TABLE 2.—*Plant intercepts* [1] *on three burns compared with adjacent unburned areas, 1954*

Species	Supai		Cosnino			Winona	
	Unburned	Burned shrub community	Unburned	Burned shrub community	Burned grass community	Unburned	Burned grass community
	Percent [1]	*Percent* [1]	*Percent* [1]	*Percent* [1]	*Percent* [1]	*Percent* [1]	*Percent* [1]
Trees:							
Utah juniper	5.00	0.00	0.00	0.00	0.00	0.00	0.00
One-seed juniper	.00	.00	17.44	2.60	.00	17.64	5.83
Pinyon	26.70	.30	25.84	2.50	.60	22.00	.00
Total	31.70	.30	43.28	5.10	.60	39.64	5.83
Shrubs:							
Big sagebrush	2.30	16.95	.00	.00	.00	.00	.00
Eriogonum	.15	.45	.00	.00	.00	.00	.00
Ephedra	.00	.15	.00	.00	.00	.00	.00
Rabbitbrush	.00	.00	.00	12.37	.10	.00	3.30
Other shrubs	.55	.00	.00	.00	.00	.00	.00
Total	3.00	17.55	.00	12.37	.10	.00	3.30
Mid-grasses:							
Red three-awn	.02	.14	.00	.03	.25	.00	.00
Arizona three-awn	.00	.00	.00	.00	.00	.00	.04
Bottlebrush squirreltail	.03	.00	.00	.00	.00	.00	.00
Total	.05	.14	.00	.03	.25	.00	.04
Short-grasses, blue grama	1.11	1.00	.15	2.05	4.85	.29	3.66
Mid- and short-forbs	.00	.01	.00	.00	.00	.00	.00
Prostrate forbs	.48	.20	.00	.01	.00	.00	.00
Half-shrubs, broom snakeweed	.02	2.00	.20	.27	.07	.00	.20
Annuals	.01	.00	.02	.11	.01	.00	.01

[1] Trees, shrubs, other woody perennials, and half-shrubs were measured by canopy intercept, and plants in the other groups by basal intercept.

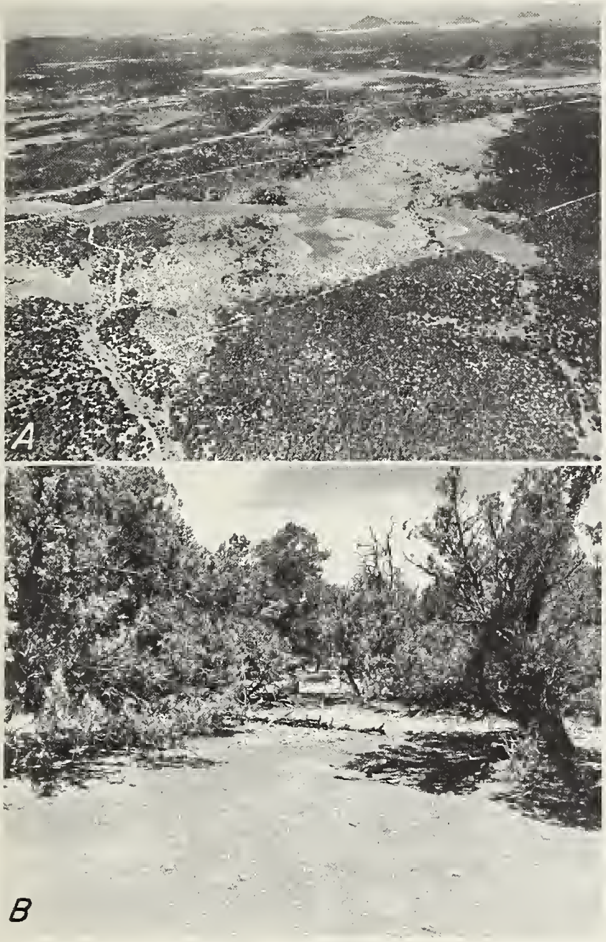

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FIGURE 10.—*A*, Aerial view of Cosnino burn near Flagstaff, Ariz. A rabbitbrush-blue grama community characterizes the southwest end of the burn, while the northeast end is predominantly blue grama; *B*, pinyon-juniper stand adjoining the burn.

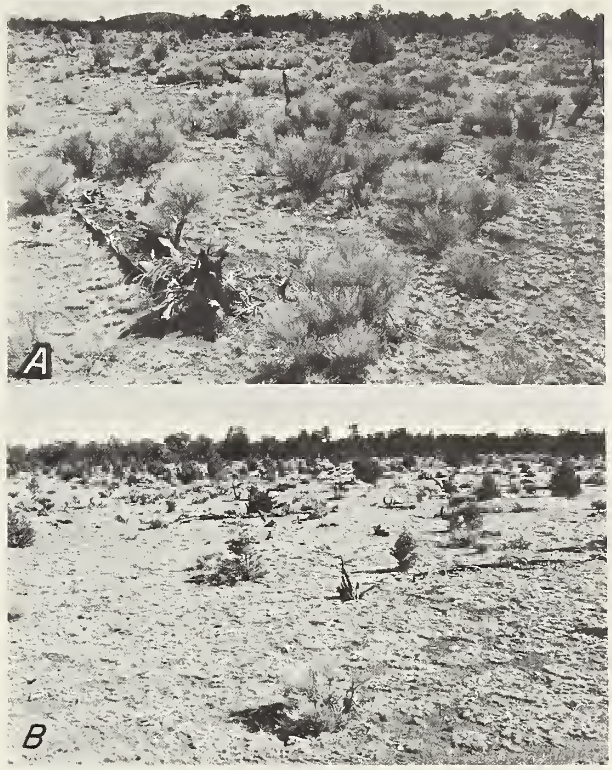

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FIGURE 11.—*A*, Rabbitbrush-blue grama community at southwest end of Cosnino burn; *B*, blue grama community at northeast end of Cosnino burn is being reinvaded by juniper and pinyon.

A third burn was studied near Winona, 20 miles east of Flagstaff. Judging from a ring count on a pinyon that had grown up within a charred skeleton, the fire occurred about 1865. The direction of the fire, as in the Cosnino burn, was along a southwest-northeast axis. The burn is characterized by a blue grama community that is being reinvaded by pinyon and juniper. Tree invasion is from the unburned stands on the periphery toward the center of the burn.

The canopy intercept of pinyon and juniper averaged almost 40 percent in the unburned stands adjacent to the Winona burn. In contrast, the canopy intercept of reinvading trees on the burned area was only 15 percent of that of the unburned stand. Blue grama covered 13 times more area on the burned than on the unburned area.

Successional recovery after fire in dense stands of pinyon-juniper begins with the establishment

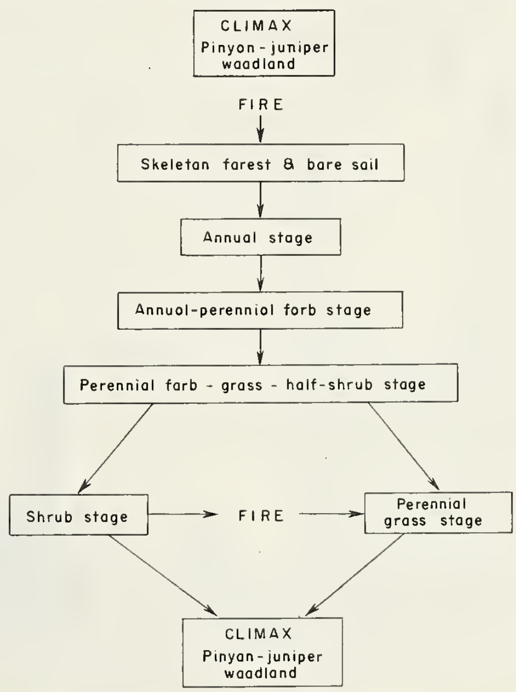

FIGURE 12.—Possible stages of succession after a fire.

of annuals. On the burns studied, the annual stage reached a peak in the second and third years. An annual-perennial forb stage develops during the third year, and by the fourth year perennials are more abundant than annuals. Perennial grasses also become common by the fourth year. Half-shrubs become important by the fourth year and continue to increase into the sixth year. From this point, successional recovery takes one of two courses. A perennial shrub stage will likely develop if shrubs such as sagebrush and rabbitbrush are present. Without shrubs, the perennial forb-grass stage may give way to a perennial grass community. If the shrub stage develops, it may be converted to a grassland stage by a second fire.

When protected from recurring fires, both the shrub and grassland stages will be reinvaded by trees, and the pinyon-juniper climax will recur. Possible stages of succession after a fire are presented graphically in figure 12.

Relation of Understory Vegetation to Tree Canopy

Cover of Understory Vegetation

Stands of pinyon-juniper range from open, scattered stands of small trees to dense stands of large trees. The relation of understory vegetation to this variation in canopy of overstory trees was determined from 379 50-foot line transects located at random within plots that had been protected from livestock grazing from 1940 to 1953. One hundred and forty-six of these transects were far enough from juniper and pinyon trees to be free from their influence. The remaining 233 transects were grouped according to canopy intercepts of overstory trees by 10-percent intervals. Measurements of the understory vegetation are summarized for the transects in each of the canopy classes in table 3 and figure 13.

Canopy intercepts of shrubs were greatest for the 146 transects with no tree overstory. Except for the 41–50 percent and 51–60 percent classes, total intercept of shrubs generally decreased as the overstory juniper and pinyon increased. The increase in shrubs in the 41–50 percent canopy class was due to algerita and cliffrose, and the increase in the 51–60 percent class was due to cliffrose and other shrubs. These irregularities do not represent trends because site conditions were not the same for all transects. On the range, overstory juniper and pinyon tended to reduce the amount of browse of such highly palatable species as winterfat (fig. 14) and shrubby eriogonums. Such woody perennials as cacti, yuccas, and agaves were usually quite sparse, and measurements showed no definite relationship to the density of overstory trees.

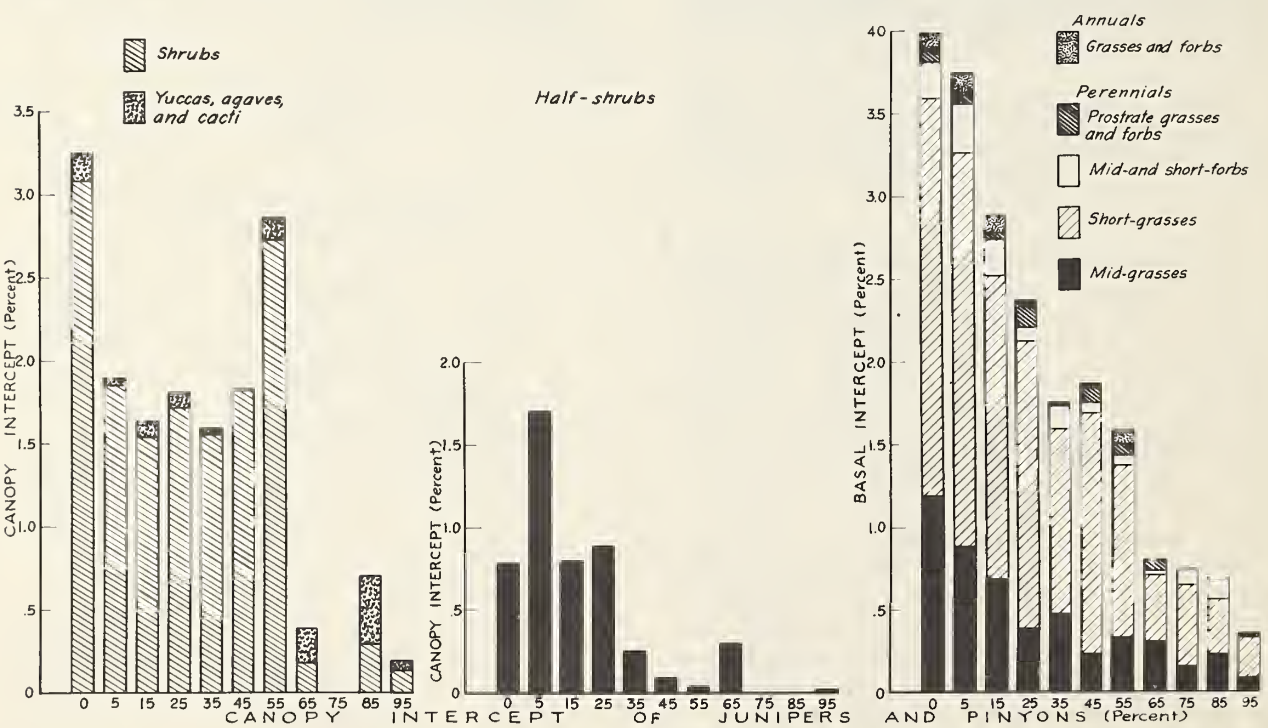

FIGURE 13.—Relation of understory woody perennials, half-shrubs, and herbaceous plants to canopy intercept of juniper and pinyon trees.

TABLE 3.—*Intercept of understory vegetation related to line intercept of overstory trees*

Species	Line intercept [1] of trees (percent)—										
	0	1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100
Perennials:											
Shrubs:											
Wright eriogonum	1.73	0.49	0.42	0.27	0.06	0.00	0.08	0.04	0.00	0.08	0.08
Rabbitbursh	.87	.45	.17	.13	.00	.00	.00	.00	.00	.00	.00
Algerita	.00	.00	.46	.39	.64	1.07	.08	.00	.00	.00	.00
Cliffrose	.00	.31	.00	.01	.19	.57	1.22	.00	.00	.20	.00
Shrub live oak	.07	.14	.19	.39	.00	.00	.00	.00	.00	.00	.00
Others	.41	.46	.30	.53	.67	.19	1.35	.14	.00	.01	.05
Total	3.08	1.85	1.54	1.72	1.56	1.83	2.73	.18	.00	.29	.13
Other woody perennials:											
Pricklypear and cholla	.15	.04	.09	.05	.03	.00	.13	.00	.00	.41	.06
Others	.02	.00	.00	.04	.00	.00	.00	.21	.00	.00	.00
Total	.17	.04	.09	.09	.03	.00	.13	.21	.00	.41	.06
Mid-grasses:											
Western wheatgrass	.47	.07	.20	.04	([2])	.09	.00	.09	.00	.11	.00
Squirreltail	.11	.17	.13	.06	.10	.02	.02	.01	.04	.02	([2])
Three-awn	.34	.11	.08	.08	.07	.03	.05	.01	.01	([2])	.00
Side-oats grama	.03	.22	.09	.04	.16	.01	.01	.03	.00	.04	.01
Black grama	.07	.01	([2])	.04	([2])	.03	.03	.04	.00	.01	.00
Mutton bluegrass	.01	.11	.02	([2])	.01	.01	.00	([2])	.01	.00	.02
Others	.16	.20	.18	.14	.14	.05	.22	.13	.09	.05	.06
Total	1.19	.89	.70	.40	.48	.24	.33	.31	.15	.23	.09
Short-grasses:											
Blue grama	2.36	2.29	1.73	1.70	1.11	1.46	.97	.40	.51	.34	.24
Others	.05	.09	.10	.03	.01	([2])	.07	([2])	.00	([2])	.00
Total	2.41	2.38	1.83	1.73	1.12	1.46	1.04	.40	.51	.34	.24
Perennial mid- and short-forbs	.22	.30	.22	.09	.14	.06	.06	.02	.09	.12	.00
Prostrate grasses and forbs:											
Ring muhly	.08	.06	.02	.10	.00	.07	.07	.00	.00	.00	.00
Others	([2])	.01	.02	.04	([2])	.03	([2])	.01	.00	.00	.00
Total	.08	.07	.04	.14	.00	.10	.07	.01	.00	.00	.00
Half-shrubs:											
Broom snakeweed	.73	1.55	.71	.78	.25	.08	.03	.29	.00	.00	.01
Others	.05	.15	.09	.10	.00	.00	.00	.00	.00	.00	.00
Total	.78	1.70	.80	.88	.25	.08	.03	.29	.00	.00	.01
Annuals	.09	.11	.10	.01	.01	.01	.07	([2])	.00	.00	.02
Transects	98	53	37	46	23	16	12	19	6	8	8

[1] Trees, shrubs, other woody perennials, and half-shrubs were measured by canopy intercept, and plants of the other groups by basal intercept.
[2] Trace.

Basal intercepts of perennial grasses were greatest on the transects with no tree influence. Perennial grasses and perennial forbs decreased with increasing canopy of overstory pinyon and juniper. Mid-grasses averaged about a third of the total perennial grass cover under both the dense and light stands of juniper and pinyon. Perennial grass and forb species totals followed the class totals, and they generally decreased with an increase in canopy. Though sparse, blue grama was the most abundant plant under the denser tree canopies. When the cover of perennial grasses and forbs under the juniper stands is sparse, annuals invade the barren soil surfaces if excess

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FIGURE 14.—Winterfat (low, light-colored shrub) does not extend into pinyon-juniper stand because of suppression by overstory trees. A highly palatable browse, winterfat, increases and spreads after overstory trees are removed.

moisture and favorable temperatures occur at the same time. However, there were few annuals, and their abundance had no consistent relationship to the overstory.

The canopy intercept of half-shrubs was less than 1 percent on the transects in protected grassland openings. Broom snakeweed was the most important species. It was most abundant where the canopy was 30 percent or less. Where tree canopy was greater, broom snakeweed decreased with increasing canopy of overstory trees.

Herbage Production

The relation of weight of air-dry understory grasses and forbs to the stand density of pinyon and juniper was determined from 186 clipped samples. Each herbage sample was obtained by clipping a 4-inch strip at ground level along a 50-foot line transect. Weights of the air-dry samples were converted to pounds per acre. The samples were taken from protected plots or from winter grazed ranges after the vegetation attained its full growth. Thirty of the 186 samples were collected from transects beyond the influence of trees. The remaining 156 samples, collected from transects with overstory trees, were grouped and summarized by canopy classes (fig. 15).

The yield curve is closely related to the results presented in table 3 and figure 13, which show that grasses and forbs decreased with increasing tree canopy.

Transects with no intercept of juniper and pinyon produced an average of 620 pounds of air-dry herbage per acre. Production was 40 and 65 percent less on transects with 10- and 30-percent canopy intercepts, respectively. On transects with a 50-percent intercept, the herbage yield of grasses and forbs was 82 percent less than the yield on transects without tree influence.

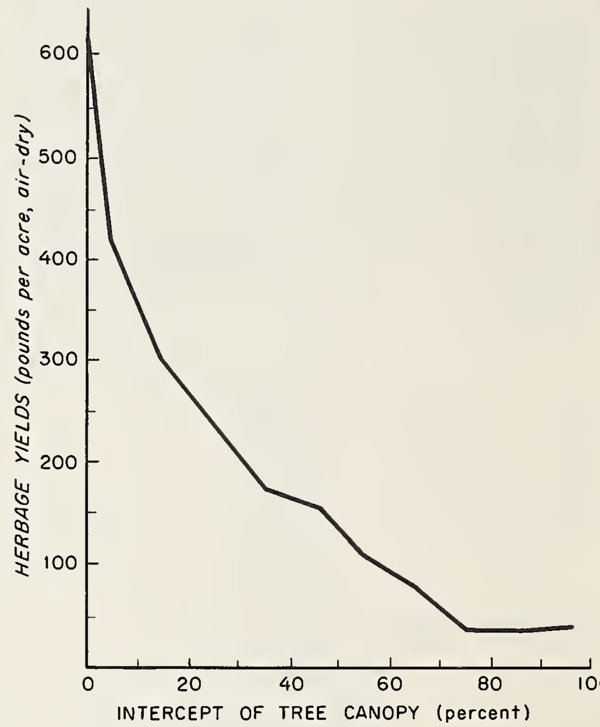

FIGURE 15.—Relation of air-dry herbage yield to percent canopy intercept of overstory juniper and pinyon.

Pinyon-Juniper Control by Mechanical Methods

Cabling or Chaining

Cabling or chaining is probably the best method for uprooting dense stands of old pinyon-juniper trees (fig. 16). About 300 feet of 2-inch cable or ship's anchor chain is dragged between two tractors of at least 150-drawbar horsepower. The cable or chain is looped behind the tractors so that trees are uprooted in a swath about 100 feet wide. The higher the speed, the better the kill. However, even at high speeds, the cable slips over small trees (10 feet high and smaller) and merely tips over many intermediate-size trees. While the method gives only a 50- to 80-percent kill, it is fairly effective on dense, mature woodland stands on terrain that is fairly smooth and comparatively

FIGURE 16.—Controlling juniper by chaining.

free of rocky outcrops. The kill can be further increased by bulldozing trees missed by the cable or chain.

Cabling not only leaves small trees, but as much as 50 percent of the ground may be covered with slash and debris. Light, scattered piles of limbs and branches improve soil moisture and protect small patches of grasses to help reseed ranges. However, heavy slash poses a serious problem (fig. 17). Because juniper is resistant to decay, large trunks and branches remain undecomposed for many decades. The release of young trees combined with the heavy layer of slash and debris may, after several years, result in a stand of trees nearly as dense as the original ones. Burning and other followup treatments have been used to remove excessive slash and kill young trees left by cabling.

Bulldozing

Bulldozers are used to uproot individual trees in stands that are too open for mass treatments such as cabling. Many types of equipment are used in bulldozing; only a few types are described here.

One bulldozer (fig. 18*A*) has a small dozer blade with a hinged pusher bar mounted on the dozer frame. The blade is usually mounted on a tractor of less than 100-drawbar horsepower. The pusher bar tips over the tree, and the blade catches the partially uprooted tree. The tractor must be reversed after it uproots each tree.

The hula-dozer (fig. 18*B*), developed by the U.S. Forest Service, is equipped with a pusher bar and dozer blade that can be tilted to the right or left by hydraulic power. The dozer is equipped with four removable teeth, two near the middle of the blade and one at each end. This equipment requires a tractor of 100- to 125-drawbar horsepower. The trees are scooped out with the right or left corner of the dozer blade. Most trees can be uprooted without backing the tractor. The reverse gear is used only in uprooting large trees. The main advantage of the hula-dozer over the nontilting blades is that less time is lost in backing the tractor away from the trees.

The tree lift is a hydraulic scoop mounted on a heavy commercial wheel tractor. The teeth at the base of the scoop can be raised or lowered by

F–503474

FIGURE 17.—Aerial view of area where juniper and pinyon trees were cabled. Note that much of the area is covered with heavy slash and debris.

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FIGURE 18.—*A*, Conventional dozer with pusher bar; *B*, hula-dozer with tiltable pusher bar and dozer blade.

hydraulic controls. Two forward movements are usually required to uproot medium or large trees. In the first, the tree lift is raised to push over the tree (fig. 19). The tractor is then reversed and the lift lowered. In the second operation, the scoop lifts the tree out by the roots as the tractor moves forward. Small trees can be scooped out with only one forward movement. The tree lift operates best in moist, rock-free soils. Although the equipment is somewhat light for large trees, it may be more efficient than heavier types in the removal of small trees. The equipment costs less than larger crawler-type tractors.

Clearing With Hand Axes

Pinyon and juniper are seldom cleared with hand axes because labor costs are high, even for open stands. However, Fort Apache Indians, using hand axes extensively, had cleared some 95,000 acres by the end of 1958 [6] (fig. 20).

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FIGURE 19.—Tree lift in first operation (A) pushes over a large pinyon; second operation (B) lifts the tree out by the roots.

FIGURE 20.—Clearing juniper with hand axes on the Fort Apache Indian Reservation.

Clearing with hand axes is generally more thorough than with heavy equipment, which usually misses small trees. Hand axes and grubbing hoes are suitable for clearing small, scattered trees that are just beginning to invade grassland ranges, and for maintaining cleared areas against reinvasions.

Clearing With Motorized Saws

Motorized saws such as two-wheeled and tractor-mounted circular powersaws and portable circular saws have received little use in clearing pinyon and juniper from Arizona ranges. With circular saws, the chance of hitting rocks and breaking blades is greater, since the saws are held near the ground to get below the lowest branches. However, since about 1954, light, powerful, one-man chain saws have proven practical. These saws can be equipped with "brush bars" for cutting small stands.

Effects of Mechanical Juniper Control on Vegetation

Plant Cover

To study effects of removal of overstory trees on understory plants, pinyon and juniper were controlled by cabling, dozing, and hand chopping on transects in 29 sites. Companion transects were located in uncontrolled stands at 23 sites adjacent to the controlled areas. Results of measurements shown in figure 21 are averages from all sites, regardless of method of control. Samples taken in

[6] Personal correspondence with Albert M. Hawley, 1959.

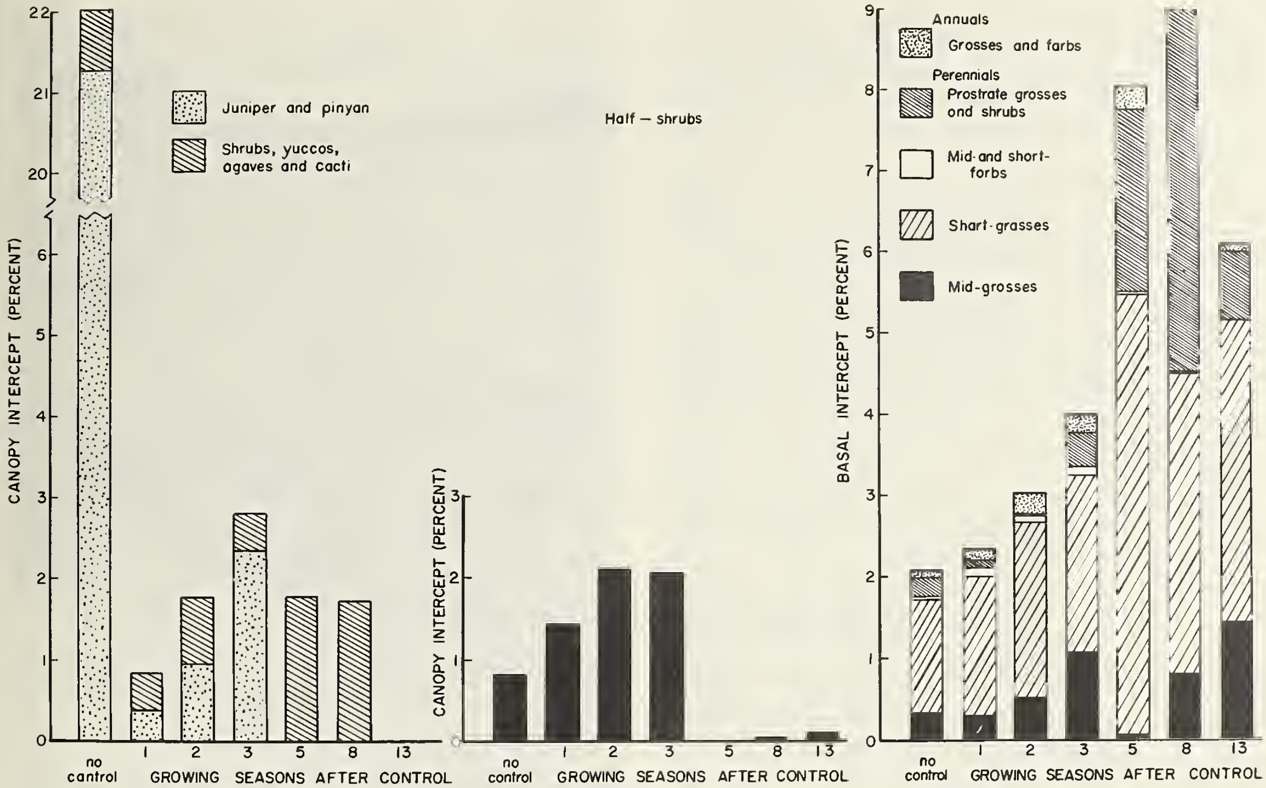

Figure 21.—Plant intercepts after juniper control: *A*, Woody species; *B*, half-shrubs; and *C*, herbaceous species.

the first 3 years after control were mainly from areas that had been cabled or bulldozed. Samples taken later were only from areas that had been hand chopped.

The immediate reduction of pinyon and juniper is shown by measurements at the end of the first growing season. The canopy intercept is that of young trees left on the cabled areas. Regrowth of juniper is indicated for the first 3 years after control because measurements from cabled areas are included in the computation. Measurements after 5, 8, and 13 growing seasons show no juniper because these areas were thoroughly cleared by dozing and hand chopping.

Pinyon and juniper grow back very slowly where clearing is thorough. On cabled areas, however, the small trees that are missed respond rapidly to release when the larger overstory trees are removed.

There was no overall pattern of response of shrubs to the removal of trees. Shrubby eriogonums at 5 years and yuccas at 8 years accounted for most of the shrubs and other woody perennials.

Removal of trees resulted in a marked increase in half-shrubs, primarily snakeweed. Snakeweed, which was suppressed, was released abruptly by the removal of the trees (fig. 22). Canopy intercepts of the half-shrubs increased during the second and third growing seasons after control. The small amounts of half-shrubs in the areas 5, 8, and 13 years after control could have resulted from the effectiveness of hand chopping, which did not disturb the soil as much as cabling. Also, there may have been some displacement by perennial grasses.

F–503466

Figure 22.—Ring of snakeweed that was released after the removal of a juniper.

Mid-grasses, particularly three-awns and side-oats grama, generally showed greater basal intercepts as the number of growing seasons increased, although lesser amounts were found on sites representing their fifth and eighth growing seasons.

Western wheatgrass, a cool-season grower, responds rapidly to the removal of pinyon and juniper, particularly on heavy swale soils, where it is a prominent part of the understory vegetation.

Of the short-grasses, blue grama was by far the most important. It continued to increase in basal intercept through at least the fifth year after control. In fact, blue grama was almost three times as dense 8 to 13 years after control as before control.

Forbs showed no marked response to control treatments.

Prostrate species showed no consistent response to the control of overstory trees. Great densities of prostrate perennials were recorded after five and eight seasons of growth following control. The abundance of prostrate species on these sites was probably due to heavy grazing before control.

Annuals increased during the first two growing seasons after control, and they were still abundant on the sites representing the fifth season of growth. After the fifth season, however, annuals declined as they were displaced by perennials.

F—503460, 503459

FIGURE 23.—*A*, Area cleared of juniper in 1949 produced 550 pounds of herbage per acre in 1953; *B*, adjacent untreated juniper stands produced 50 pounds per acre in 1953. Photo *B* was taken from the same point as photo *A*. Fort Apache Indian Reservation.

Herbage Yields

Increases in herbage yields as a result of clearing were determined from 192 clipped samples. Samples of forage species were clipped from 4-inch by 50-foot plots, air-dried, weighed, and converted to pounds per acre. Samples were clipped from protected exclosures and from winter ranges after the middle of September to get the full season's growth. Only areas cleared by bulldozing and hand chopping were included so that full release of understory forage species could be measured (fig. 23). The areas sampled had had 0, 1, 2, 3, 5, 8, and 13 seasons of growth following clearing.

A curve calculated from the total production on juniper-control areas (fig. 24) shows that herbage production increased until about 10 years after the control operations—from 198 pounds per acre before juniper control to about 690 pounds 10 years later. The maximum production that can be expected is probably about 700 pounds per acre. Although the data are not conclusive, maximum herbage production probably occurs 5 to 10 years after control.

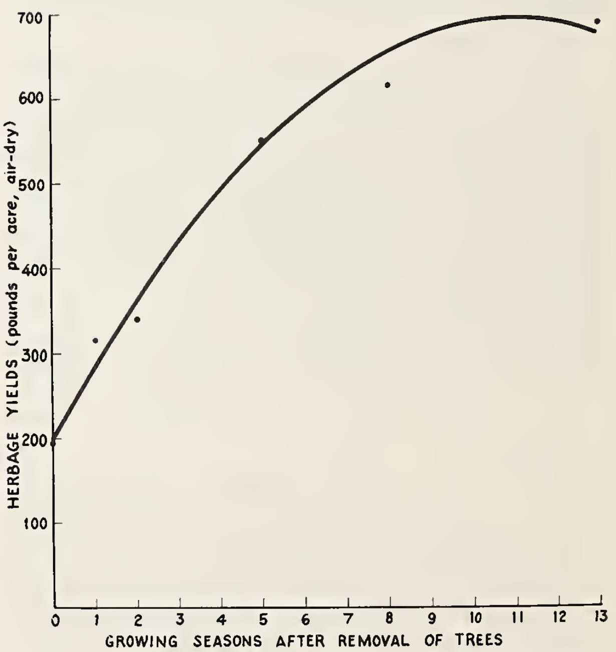

FIGURE 24.—Air-dry herbage yields by number of growing seasons after control of juniper and pinyon. The regression equation is $y=198.56+88.88\ x-4.02\ x^2$.

Effects of Light Slash on Grass Growth

Beneficial effects of light slash on grass growth have often been observed after juniper control. Measurements on a plot 7 miles east of Ashfork, Ariz., illustrated this effect. In 1951, cabling of juniper left a layer of slash plus some live trees

that were missed or partially uprooted. During the fall of 1953, the trees missed by cabling were killed by hand chopping. Slash was removed from half the plot and lightly scattered over the other half. Ten transects in each subplot were measured in 1953 and remeasured in 1954 after one growing season. Basal intercepts (percent) of grasses in 1953 and 1954 on the two plots were as follows:

	1953	*1954*	*Difference*
Slash present:			
Side-oats grama	0. 186	0. 282	+0. 096
Blue grama	2. 998	4. 858	+1. 860
Arizona three-awn	. 010	. 016	+. 006
Squirreltail	. 000	. 028	+. 028
Total	3. 194	5. 184	+1. 990
Slash absent:			
Side-oats grama	. 032	. 044	+. 012
Blue grama	3. 832	4. 710	+. 878
Arizona three-awn	. 030	. 070	+. 040
Squirreltail	. 000	. 000	. 000
Total	3. 894	4. 824	+. 930

Side-oats and blue gramas increased more under slash, and squirreltail became established there. Arizona three-awn increased more without slash. The total increase in grass cover intercept was 1.990 under the slash, compared with 0.930 without slash, even though the initial grass cover was greatest on the area not covered with slash.

The plot with light slash produced 93 pounds of air-dry herbage per acre; this was 35 percent more than the plot with no slash.

The favorable effects of light slash on herbaceous plants (fig. 25) can be attributed both to protection from grazing and improved moisture conditions (Glendening 1942). Protection from grazing allows the development of more vigorous plants and the production of a better seed crop. Soil moisture is improved because the slash catches and holds snow and reduces evaporation.

Pinyon-Juniper Control by Burning and its Effect

F–503458, 503461

FIGURE 25.—Benefits of slash for grass growth near Payson, Ariz.: *A*, Light slash left by juniper control favors growth of grasses by providing partial shade, by catching snow in winter, and by temporarily protecting plants from grazing; *B*, a light layer of slash aids in artificial reseeding (left) while absence of slash reduces the success of reseeding (right).

The use of fire to control pinyon-juniper stands has been tried by ranchers and by State and Federal agencies. Fire is being tested in several ways: (1) The broadcast burning of mature tree stands, (2) the burning of grasslands to kill invading trees, (3) the burning of individual trees where neither the trees nor the understory plants are dense enough to carry fire, and (4) the burning of slash and debris left after the use of other methods of control.

Broadcast burning of live stands of pinyon-juniper has been tried on the Aja Ranch, on U.S. Bureau of Land Management ranges, on the Lakin Allotment of the Prescott National Forest, and on the Fort Apache and Hualpai Indian Reservations. These trials have shown that burning pinyon-juniper stands is difficult and requires special conditions. Stands have to be dense to carry fire, usually over 400 trees per acre. Both old and recent accidental burns seem to have had more than 50 percent pinyon, but this high percentage has also been found in the more dense stands. Even in these stands, fire will carry only during the hot, dry, windy weather when any burning is hazardous.

The 1953 unintentional burn on the Hualpai Indian Reservation, which burned extensive acreage, was seeded after the fire. Because of good stand of grass was attained, attempts were made to intentionally burn and then seed additional areas in subsequent years. The fires were successful in 1956 when 4,500 acres was burned, a partial success in 1957 when 1,200 acres of a larger planned area was burned, and a near failure in 1958 when only 200 acres was burned along a 2-mile fireline. Fire seemed to carry well through tree stands during high temperatures, low humidity, moderate winds,

and long preceding periods of little precipitation. Because of these four requirements, burning could be done only a few days each year, and in 1 year the necessary conditions did not occur.

These burns were made where deep canyons and broad areas of sparse grass cover provided wide firebreaks. Many spot fires developed at least one-half mile ahead of the main fires. If this type of burning were to be extended to other areas, similar use of natural firebreaks or construction of wide firelines would be needed.

The Hualpai burns were seeded, and generally the seedings were successful (fig. 26). Best records are available for the 1953 burn, which was broadcast seeded in 1954. Forage production of the seeded stand was estimated in 1958 by clipping five clusters of plots located at random distances along the road through the burn. Ovendry weights ranged from 134 to 803 pounds per acre, and averaged 390 pounds per acre. Less than 50 pounds per acre of native grass was produced on the adjacent unburned area. Crested wheatgrass was by far the most abundant species, and it dominated the aspect of the burn where the seeding was a success. Sand dropseed and western wheatgrass were also important.

The seeding success on these burns is in contrast to the much poorer results of seedings on many areas in the pinyon-juniper type. Further studies are needed to determine the best time for burning and seeding and the best adapted species.

Because broadcast burning is in the experimental stage, more knowledge on methods and results is needed before it can be recommended as a general practice.

Burning of individual trees can be used in stands too open to carry fire. In one method, the lower branches are cut and allowed to fall around the base of each tree. The branches are then fired when thoroughly dried. The Fort Apache Indians commonly use this method to kill large alligator junipers that are difficult to remove mechanically.

A backpack pressure pump filled with diesel oil has been used to apply the fuel needed to kill trees. The oil is sprayed over a burning wick and directed at the base of each tree.

Several types of butane and propane burners are used. Single or double jets mounted at the end of a long aluminum tube are used to direct the flame to the tree bases (fig. 27). A pilot flame ignites the burst of gas.

Burning grassland communities to kill small, invading trees has been tried by a few ranchers and on the Coconino National Forest. Grass fires readily kill trees up to 3 feet in height. The percentage of kill decreases as the size of trees increases. Large trees are protected against fire by a zone too sparsely covered with herbaceous fuels to carry fire. These observations are supported by results reported by Martin and Crosby (1955) for burning tests on redcedar in Missouri.

To test the effectiveness of grass fires in killing one-seed juniper trees, two burns were conducted, in January and March 1956, on the Coconino National Forest north of Flagstaff, Ariz. (Jameson 1962). A wildfire, in June 1956, on land of the nearby Wupatki National Monument, provided additional information. The burns were in grassland, in a community where the herbage composition was about 88 percent galleta and 10 percent black grama; the additional vegetation was largely broom snakeweed, Russianthistle, blue grama, and other plants. About 60 trees per acre had invaded the type.

There was an initial loss in grass cover the first year, but grasses soon recovered. By 1958, grass

Arizona State Land Department photo.

FIGURE 26.—A stand of seeded grasses on a burn on the Hualpai Indian Reservation.

F–503475

FIGURE 27.—Butane gas burner being used to kill a juniper.

production was about the same on the burned and unburned areas.

By 1958, counts showed that from 70 to 100 percent of trees less than 4 feet high were killed in all burnings, but only 30 to 40 percent of trees 5 to 6 feet high were killed. On the March and June burns, 60 to 90 percent of trees 8 to 10 feet high were killed. This increase is attributed to the accumulation of Russianthistle and other forbs that burned under the larger trees.

Prior to burning there was no important difference in the vegetation between the different burned areas. Differences in results observed were attributed to direction of the prevailing wind. Where the burns were against the prevailing wind, the tumbleweed around the larger trees was not ignited and kill of the larger trees was less than 10 percent.

The use of grass fires is largely limited to grasslands that are being invaded by small trees. Grazing animals must be withheld prior to burning so that enough fuel to carry fire can be accumulated. If fire damage is heavy, a burned-over area may need protection from grazing for one growing season after it is burned to give grass plants a chance to recover.

Like burning of tree stands, burning of grasslands to control small juniper is still in the experimental stage. More knowledge is needed on how and when to burn to obtain the best juniper kill and the least damage to the grass. Also, adequate firebreaks and other safeguards are essential.

Burning of slash is a followup method used where a mechanical treatment was the primary control method. Where the original stand was dense, the resultant slash may be very heavy (fig. 28).

F—503480

FIGURE 28.—Burning juniper slash to remove debris left after cabling.

Unlike light slash, heavy slash shades out grass, may absorb considerable moisture, interferes with the handling of livestock, and increases the difficulty of subsequent mechanical treatment. Also, small trees that are missed grow two to three times as fast after release from the dominance of larger overstory trees.

A test was made to determine whether excessive slash and living trees left by cabling could be burned without causing excessive damage to forage species. The test was planned and set up on the Hay Lake Allotment south of Winslow, in cooperation with the Coconino National Forest and the Bar-T-Bar Ranch. To avoid concentrations of cattle, test plots were located in a cabled area away from water developments and away from roads. Eight 6-acre plots were arranged in a band perpendicular to the general slope. This strip arrangement was used to prevent runoff from one plot from influencing another plot. Treatments were: Unburned, burned December 1–3, 1954, burned April 6, 1955, and burned August 2, 1955. They were assigned at random to the eight plots.

Each burn plot was divided into 10 subplots, and a 100-foot line transect was located at random in each subplot. Measurements in 1955 included: (1) Intercepts of slash and needle litter, (2) intercepts of ground surfaces that showed evidence of burning, (3) canopy intercepts of live trees and shrubs left by cabling, and (4) basal intercepts of grasses and forbs. In 1956 and 1958 intercepts of live plants were remeasured.

Slash and litter covered 41 percent of the unburned check plots, but this area was reduced to 24 percent in the December burn, 27 percent in the April burn, and 20 percent in the August burn. Fire consumed much of the stems and branches of the uprooted trees but left much of the leaf and needlecast. Slash cover was reduced by 43 percent.

The area burned was 23 percent on the December burn, 22 percent on the April burn, and 35 percent on the August burn.

Live trees left after cabling were reduced by 80 percent by the burns, from an average of 6.5 percent cover on the unburned areas to 1.3 percent on the burned areas. The greatest reduction was from the August burn. Other woody plants were too scattered to permit a determination of whether they were affected by the burning.

Blue grama was the only abundant grass in the area. It may have been reduced some during the first year by the December and April burns, and more by the August burn. It had recovered, however, by the time of measurement in the second year. In 1958, production of blue grama averaged 38 percent higher on the burned plots than on the unburned plot. No important differences in response were noted between the burning dates.

Snakeweed, the second most abundant plant, increased from 1955 to 1958. It was least abundant on the August burn and most abundant on the unburned check. Annual plants reacted similarly

on the burned and unburned plots but were more abundant on the December and April burns than on the unburned check. Perennial forbs were sparse in 1955, reached a peak in 1956, and were again sparse by 1958.

Spots covered with ashes where a heavy accumulation of slash and debris had burned were most affected by the fire. Their ability to absorb water was reduced by 60 percent, and midday temperatures were generally 5° F. higher than on unburned areas. Vegetation did not become established immediately on the burned areas. However, water runoff from the burned spots increased grass growth on the areas immediately adjacent. Soil samples tested in the greenhouse showed some increased fertility due to burning.

Juniper Control by Chemicals

The use of herbicides to control junipers is still in the experimental stage. Recent work by the Agricultural Research Service, U.S.D.A., has shown that chemical control of junipers may be practical and may eventually be one of the cheapest control methods. Both foliage spray applications and soil applications have been effective in treating individual trees in experimental plots. Small-scale broadcast treatments have shown some promise, but broadcast treatments have not been tried on a large scale. The polychlorinated benzoic acids applied in oil have been the best foliage spray application, while use of pelleted fenuron has been the best soil treatment.

Costs and Benefits of Principal Control Methods

Costs

The number of acres cleared (fig. 29) and the cost of clearing pinyon-juniper stands have been summarized through 1956,[7] and data for the more common methods of control are shown in table 4. Costs of the different methods are not directly comparable because different types of stands were treated.

Costs of cabling were obtained from 191 projects that covered 245,350 acres. High costs occurred where dense stands included exceptionally large trees and where terrain was rough and rocky. Costs were also high where two cables were used or where cabling was repeated a second time in a different direction. Costs were low where mature trees occurred in open stands and where terrain was smooth. Costs were lower for large projects. Cotner (1963) found that costs were much greater when cabling projects covered less than 3,000 acres.

Followup treatments after cabling result in additional costs. These treatments have included bulldozing, hand chopping, and burning. Reseeding to hasten recovery after burning adds still more cost. Despite followup costs, cabling followed by supplementary treatments is cheaper than bulldozing for dense stands of mature trees.

Costs for bulldozing were determined from 334 projects on 163,867 acres. Maximum costs occurred where dozing was used to clear dense stands from small acreages; minimum costs occurred where open stands of small trees were cleared on large acreages. Followup control treatments are not usually needed after bulldozing.

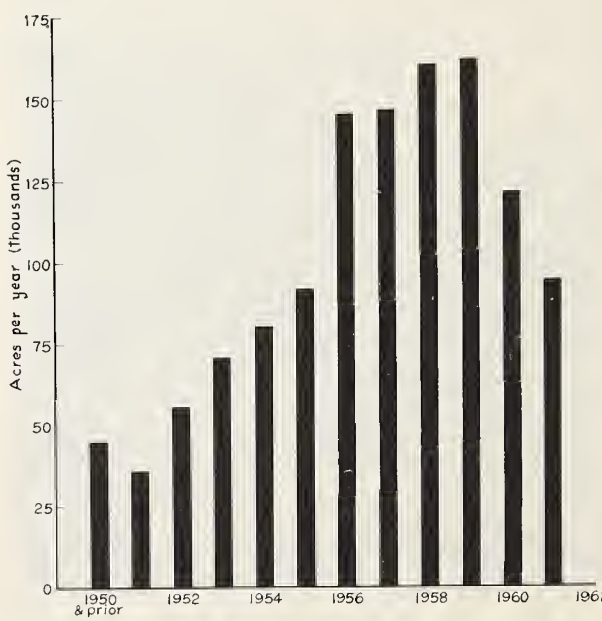

FIGURE 29.—More than a million acres of pinyon-juniper has been treated in Arizona, 1950–61 (data of Cotner).

[7] Data obtained from unpublished reports of U.S. Agricultural Stabilization Committees, Forest Service, Bureau of Land Management, and Bureau of Indian Affairs were summarized by M. L. Cotner, Farm Economics Research Division, Agricultural Research Service, U.S. Department of Agriculture.

TABLE 4.—*Costs of some juniper control projects in Arizona, 1950–56* [1]

Method	Cost per acre			Control projects included	
	Minimum	Maximum	Average [2]		
	Dollars	*Dollars*	*Dollars*	*Number*	*Acres*
Cabling[3]	0. 55	11. 00	1. 60	191	245, 350
Bulldozing[3]	. 50	34. 28	3. 55	334	163, 867
Hand chopping, sawing, and grubbing	. 69	21. 23	5. 91	102	93, 310
Burning	. 27	10. 00	1. 74	7	3, 970

[1] Data from M. L. Cotner supplemented.
[2] Total cost divided by total acres.
[3] Operations with followup treatments are excluded.

Costs of hand chopping, sawing, and grubbing are from 102 projects on 93,310 acres. Most of this work has been done on the Fort Apache and San Carlos Indian Reservations. Maximum costs occurred where dense stands were cleared. Minimum costs occurred where open stands of trees 2 to 3 feet high were cleared with hand axes. Where all trees are small, hand chopping is often the cheapest method (Cotner 1963). Clearing with hand axes usually required no followup treatments.

The minimum costs for hand chopping indicate the costs that may be expected in maintaining cleared areas against reinvasions. Frequency of maintenance operations will depend upon the thoroughness of initial clearing operations, and they may be necessary only at 10- to 20-year intervals.

Costs presented on burning treatments are not very meaningful because only seven projects were reported. The cost of individual tree burning has been discussed by Cotner and Jameson (1959). Stands of 50 small trees per acre are expected to cost about $1.90 per acre for individual tree burning, while stands of 150 large trees per acre are expected to cost more than $12.00 per acre. No information is available on the cost of grass fires needed to kill small juniper trees.

Benefits

Increases in forage production following juniper control often allow increases in livestock numbers or prevent reductions in livestock numbers which would result from decreasing forage supplies. The herbage increased from 200 to nearly 700 pounds of herbage per acre on the sites studied (fig. 24). On one allotment of the Prescott National Forest, bulldozing 7,100 acres of juniper at a cost of $8,412 allowed an increase in cattle from 4,480 animal-months per year before treatment in 1950 to 7,500 animal-months in 1955 (Beveridge and Ames 1956.)

Juniper control also reduces the labor required for handling livestock. Cotner and Kelso (1963) calculated that reduced labor and increased beef sales resulting from juniper control may be worth $1.19 to $3.89 per acre to ranchers, depending on the appropriate interest rates and other variables.

Release of preferred game browse species, such as winterfat, cliffrose, and shrubby eriogonums, has been noted at several areas cleared of juniper. Antelope and elk have been observed to frequent controlled areas, especially near their edges. Pinyon-juniper stands have been controlled on some of the important game ranges in the State, and operations have had little effect on deer movements (McCulloch 1962). Comprehensive studies are now underway to evaluate the relation of juniper control to game food and cover.

Effects of juniper control on soil erosion and water yields are being studied on the Beaver Creek Watershed project of the Coconino National Forest and as part of the Carrizo Creek-Corduroy Creek studies of the U.S. Geological Survey and the Fort Apache Indian Reservation.

Summary

The small amount of woody material in Arizona's 14 million acres of pinyon-juniper woodlands, the high cost of harvesting the small wood supply, the slow tree growth, and the lack of markets for pinyon and juniper products combine to discourage the management of the pinyon-juniper type as a wood-producing area. Pinyon and juniper have invaded and taken over grassland communities, and the density of established stands has increased.

Successional changes in vegetation between 1940 and 1953 were compared on protected and grazed plots. Trees and shrubs increased on both types of plots. Mid-grasses as a group increased under protection and decreased under grazing. Forbs as a group increased slightly under both protection and grazing, although some species showed minor losses on both types of plots. Blue grama, red three-awn, and other short-grasses as well as ring muhly decreased more under protection than under grazing. Half-shrubs decreased under both grazing and protection. Snakeweed was the predominant half-shrub species.

The effect of pinyon and juniper trees on understory perennials was determined by a sequence of measurements taken on areas where tree cover ranged from scattered trees to almost complete cover. In general, understory plants decreased with increasing amounts of overstory trees.

Pinyon and juniper reduce the production of understory grasses and forbs by suppressing their growth. Air-dry herbage yields ranged from

about 600 pounds per acre on transects with no tree overstory to less than 100 pounds per acre on transects with 60 percent canopy intercept. Transects with 80 percent or more canopy intercept produced less than 50 pounds per acre.

Several methods of reducing pinyon-juniper stands are widely used as range improvement practices. Cabling or chaining is an inexpensive means of uprooting dense stands of old pinyon and juniper trees, but followup treatments usually are needed. Bulldozing is being used extensively to uproot individual trees in stands that are unsuited to cabling and chaining.

No chemical has yet been recommended for general use in juniper control, although there are several promising leads.

Small-scale broadcast burning of live stands of pinyon-juniper under controlled conditions has been tried. However, more knowledge is needed before broadcast burning can be recommended as a general practice. The largest part of the pinyon-juniper type is usually too open for fire to carry from one tree to another. In open stands, oil and propane burners can be used to kill individual trees.

The burning of grassland communities to kill small, invading trees has been tried on a small scale. This method may be justified where there are many invading trees, but in scattered stands it is probably less costly to treat invading trees individually.

Removal of large overstory trees results in an immediate release of the small pinyon and juniper if they are missed in the control operation. Shrubs and half-shrubs that occur in the understory may also increase greatly. Short-grasses and most mid-grasses increase in response to juniper control.

Perennial forbs responded irregularly to clearing. Prostrate species were most abundant on areas that had been grazed. They occupied very little space in the open grasslands that were protected or grazed in winter. Annuals increased the first year and reached a peak during the second growing season after the clearing. After the second year, they decreased as they were displaced by perennials.

A light layer of slash left by the clearing of open stands favored the reestablishment of grasses and forbs. Light slash increased production by almost 100 pounds per acre in 1 year.

Excessive slash combined with the release of small trees that were missed poses a serious problem on cabled areas. In slash-burning experiments conducted in three seasons, a burn in December removed the least slash and killed the fewest trees missed by cabling. An August burn removed the most slash and killed the most trees, while an April burn gave intermediate results. There was a 38-percent increase in grass production on the burned plots after 3 years.

Cost comparisons for cabling, dozing, and clearing with hand axes show that cabling or chaining has been the least expensive control method. To obtain optimum benefits from cabling or chaining, followup treatments usually are necessary. The best use of this method is in removing stands of large trees. Small trees can often be controlled more cheaply and efficiently by individual tree treatments.

Common and Botanical Names of Plants Mentioned

Actinea, Cooper	*Hymenoxys cooperi* Cockerell
Agave	*Agave* spp.
Algerita	*Berberis fremontii* Torr.
Amaranth	*Amaranthus* spp.
Aster	*Aster* spp.
Blackbrush	*Coleogyne ramosissima* Torr.
Bladderpod	*Lesquerella* spp.
Bluegrass, mutton	*Poa fendleriana* (Steud.) Vasey
Bundleflower, James	*Desmanthus cooleyi* (Eaton) Trel.
Cactus, pincushion or mammillaria	*Mammillaria* spp.
Cholla	*Opuntia* spp.
Cliffrose	*Cowania mexicana* D. Don.
Curlymesquite	*Hilaria belangeri* (Steud.) Nash
Dalea	*Dalea* spp.
Deervetch	*Lotus* spp.
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Ephedra	*Ephedra* spp.
Eriogonum (herbaceous)	*Eriogonum* spp.
Eriogonum, Simpson	*Eriogonum simpsoni* Benth.
Eriogonum, Wright	*Eriogonum wrightii* Torr.
Euphorbia	*Euphorbia* spp.
Evolvulus, Arizona	*Evolvulus arizonicus* A. Gray
Flax, Lewis	*Linum lewisii* Pursh
Fleabane	*Erigeron* spp.
Fluffgrass	*Tridens pulchellus* (H.B.K.) Hitchc.
Galleta	*Hilaria jamesii* (Torr.) Benth.
Globemallow	*Sphaeralcea* spp.
Goldeneye, annual	*Viguiera annua* (Jones) Blake
Goldenweed	*Haplopappus gracilis* (Nutt.) A. Gray
Grama, black	*Bouteloua eriopoda* Torr.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Grama, needle	*Bouteloua aristidoides* (H.B.K.) Griseb.
Grama, side-oats	*Bouteloua curtipendula* (Michx.) Torr.
Grama, sixweeks	*Bouteloua barbata* Lag.
Groundsel	*Senecio* spp.
Groundsel, broom	*Senecio spartioides* Torr. & Gray
Hoarhound, common	*Marrubium vulgare* L.
Horsebrush, Gray	*Tetradymia canescens* DC.
Hymenopappus	*Hymenopappus lugens* Greene
Junegrass, prairie	*Koeleria cristata* (L.) Pers.
Juniper, alligator	*Juniperus deppeana* Steud.
Juniper, one-seed	*Juniperus monosperma* (Engelm.) Sarg.
Juniper, Utah	*Juniperus osteosperma* (Torr.) Little
Knotweed	*Polygonum* spp.
Loco, prostrate	*Astragalus humistratus* A. Gray
Menodora, rough	*Menodora scabra* A. Gray
Milkvetch	*Astragalus* spp.
Muhly, red	*Muhlenbergia repens* (Presl) Hitchc.
Muhly, ring	*Muhlenbergia torreyi* (Kunth) Hitchc.
Muhly, spike	*Muhlenbergia wrightii* Vasey
Needle-and-thread	*Stipa comata* Trin. & Rupr.
Nightshade	*Solanum* spp.
Oak, Emory	*Quercus emoryi* Torr.
Oak, shrub live	*Quercus turbinella* Greene
Penstemon	*Penstemon* spp.
Penstemon, toadflax	*Penstemon linarioides* A. Gray
Phlox, desert	*Phlox austromontana* Coville
Pine, ponderosa	*Pinus ponderosa* Laws.
Pinyon	*Pinus edulis* Engelm.
Pricklypear	*Opuntia* spp.
Pussytoes	*Antennaria* spp.
Rabbitbrush, rubber	*Chrysothamnus nauseosus* (Pall.) Britt.
Ricegrass, Indian	*Oryzopsis hymenoides* (Roem. & Schult.) Ricker
Russianthistle	*Salsola kali* L.
Sacahuista	*Nolina microcarpa* S. Wats.
Sagebrush, big	*Artemisia tridentata* Nutt.
Sagebrush, fringed	*Artemisia frigida* Willd.
Sagebrush (herbaceous)	*Artemisia* spp.
Saltbush, fourwing	*Atriplex canescens* (Pursh) Nutt.
Scurfpea, slimflower	*Psoralea tenuiflora* Pursh
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Squirreltail, bottlebrush	*Sitanion hystrix* (Nutt.) J. G. Smith
Sumac, skunkbush	*Rhus trilobata* Nutt.
Three-awn	*Aristida* spp.
Three-awn, Fendler	*Aristida fendleriana* Steud.
Three-awn, red	*Aristida longiseta* Steud.
Three-awn, sixweeks	*Aristida adscensionis* L.
Tridens, hairy	*Tridens pilosus* (Buckl.) Hitchc.
Tridens, slim	*Tridens muticus* (Torr.) Nash
Tumblegrass	*Schedonnardus paniculatus* (Nutt.) Trel.
Verbena	*Verbena* spp.
Vine-mesquite	*Panicum obtusum* H.B.K.
Wheatgrass, crested	*Agropyron desertorum* (Fisch.) Schult.
Wheatgrass, western	*Agropyron smithii* Rydb.
Winterfat, common	*Eurotia lanata* (Pursh) Moq.
Wolftail	*Lycurus phleoides* H.B.K.
Yarrow, western	*Achillea lanulosa* Nutt.
Yucca	*Yucca* spp.

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